This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

Library
of the
University of Wisconsin

Google

87-06

ARRANGEMENTS FOR DRIVING
UNIVERSITY MACHINE SHOP TOOLS
BY USE OF LINE SHAFT CLUTCHES

by

EDWARD JOSEPH CONNELL

A thesis submitted for the degree of

MECHANICAL ENGINEER

UNIVERSITY OF WISCONSIN

1916

TABLE OF CONTENTS

page

Introduction - - - - - - - - - - - - - - - - - - - 1

Chapter I:

Why Line Shaft Clutches are Becoming Popular - 2

Chapter II:

Losses in Line Shafting - - - - - - - - - - - - -7

Chapter III:

Bearings and Hangers - - - - - - - - - - - - - -11

Chapter IV:

Belts and Pulleys - - - - - - - - - - - - - - - 13

Chapter V:

Clutches - - - - - - - - - - - - - - - - - - - 20

Chapter VI:

Method Used - - - - - - - - - - - - - - - - - - 26

Drawings - 28

Bibliography - - - - - - - - - - - - - - - - - - - 31

INTRODUCTION

This thesis is the development of a method of driving the University Machine Shop Tools by use of Line Shaft Clutches, designed either for use in the new shops to be constructed or in the re-arrangement of the machines and methods of driving them in the present shops.

The type of drive is one which is at present coming into considerable prominence on account of its cheapness of installation and its efficiency.

The thesis was written with the view to its use in the arrangement of the proposed new University Shops.

The thesis includes a review of current literature and replies secured in answer to inquiries concerning the best and most efficient method of driving machine tools, and a layout of the Machine Shop in its proposed new arrangement.

CHAPTER I.

WHY LINE SHAFT CLUTCHES ARE BECOMING POPULAR

Driving Machine Shop Tools direct from line shafting is becoming popular for many reasons, some of which are as follows:-

Under the former method with its system of shafting and counter-shafting the overhead portion of the shops is a tangled mass of belts, throwing greasy dust on the ceilings, cutting off light and occupying valuable space. In order to take up one of these belts, it is often necessary to shut down the whole department. An example of an installation is as follows:-

An actual installation of twenty-eight double buffing wheels was driven by the usual counter-shaft drive. With ten-foot belt centers the materials listed below were used.

This system was replaced by a direct, clutch-drive system. With the same belt centers of ten feet as used in the counter-shaft system, the following materials were used:-

	Old counter-shaft System.	New Line shaft Clutch System
Pulleys	140	28
Belting - 4"	1288 ft.	644 ft.
Belts to dress, lace & take up	56	28
Bearings to oil & waste power	63	12
Shaft collars	60	8

In this installation which was but a small one and took in but one department, the following saving was effected:-

112 pulleys
644 ft. 4 in. belting
51 bearings
28 loose pulleys
52 shaft collars

All these materials formerly entered into the expense account and overhead cost. The shop, under the new installation, was light and cheerful in appearance and overhead belts entirely eliminated; belt slippage was reduced about one-half with a consequent increase in production, and the single belt to each machine can be laced or shortened at will by simply throwing out the clutch. Each machine is absolutely independent.

The best method of driving tools is by the group system. A certain set or class of machine tools are all connected to a line shaft and this line shaft is then driven by a steam engine or motor as is deemed advisable.

Individual motors for driving machine shop tools have their advantages. They have a wide range of speed and are easy to control. Both these things are taken care of in the line shaft drive. An efficient quick belt shifting device can easily be secured which will shift the belts to start or stop the machine by merely throwing a lever. The range of speed is taken care of by reducing the ratio between the highest and lowest cone speeds and then supplementing this reduced ratio with additional back gears in order to get the required overall range of speed, thereby increasing the belt speeds on all steps but most on the large ones where it is needed. High belt speeds cost nothing and advantage should be taken of the increased power which goes with it. The best method is then as follows:- the first motion shaft to be driven by a constant speed motor and the change of speed determined by a selection of pulley sizes and gears.

There are some cases where the use of individual motor drive is almost imperative. Cases of

this are (1) For portable floor plates where it is the only practicable system; (2) For isolated tools; (3) When the machine tools are arranged in such a position that line shaft layouts for their accommodation are inconvenient or impossible.

In general the increased cost of installation of motors prohibits their use. The power capacity of the individual motor must be that due to the maximum requirement of the machine to which it is attached. The machine may demand this maximum load but very seldom but the investment in the motor is there for this requirement.

In the group system of line shafting only a few of the machines are running at maximum power consumption at any one time. The result is that the average requirement of such a group is but a fraction of the sum of the maximum requirements of the individual tools. It is, then, only this average power which has to be provided for and the commercial efficiency of this system is then high as it is generally working under about normal load. Efficiency of transmission is secured by use of anti-friction bearings of ball or roller type to be treated later.

In brief the advantages of driving machinery direct from line shaft can be summed up as follows:-

When the counter-shafting is eliminated there is only one-half the transmission equipment necessary which means one-half less initial cost, one-half less friction, one-half less trouble, and repair. Moreover, under the new arrangement the machine room is much cleaner, lighter and neater.

CHAPTER II

LOSSES IN LINE SHAFTING

One of the largest problems in any system of line shafting is the elimination of unnecessary losses. Upon the amount of these losses practically depends the efficiency of the entire system.

Every factory manager is confronted with the triple problem of power generation, power transmission and power transformation. It has often been found that in many factories all possible economies have been conserved in connection with the generation of power but the efficiency of the transmission lines has been entirely neglected.

Unless the line shafting is properly aligned there will be much waste in transmission. In many cases due to this poor alignment only from one-quarter to two-thirds of the power generated is effective in doing work. Lubrication of journals and bearings is very important as it has been found that the coefficient of friction for journals properly lubricated is one-sixth that for poorly lubricated journals.

Lines of shafting 100 - 150 feet in length are often found to be 5/8 " to 1 1/4 " out of alignment. This explains why 35 % loss in friction in transmission lines is common practice.

A very careful investigation and numerous tests establish the fact that the average loss of power due to friction is about 35 %. The smallest friction in a textile plant that has been found is 29 1/2 %, the largest 52 %. It is very common experience to find in these plants friction loads of from 40 % to 42 %. Of course, this condition directly affects the cost of operating, and recent tests also tend to prove that it affects the output materially. This friction is not altogether due to the shafting, that is, the pressure at the boxes, but it is also due to the tension of the belts. This includes all belts running on idlers, but the principal amount of this friction can be traced to improper leveling of shafting.

Newer systems of installations are now in use which provide efficiency and economy of line shafting operation equal to that of any steam engine. This is accomplished by proper alignment. By the intelligent use of shaft aligning devices the only cause for friction loss of power is the legitimate one of the weight of the shafts and the pull of the belts. The careful engineer can often, by locating his belts, above and below, on one side and the other, arrange things so that the whole line of shafting will all

but float, as is usual in installing the "floating" armatures of large continuous current generators.

Roller bearings and ball bearings permit of greatly reducing this line shaft friction. These bearings replace rubbing friction with rolling friction, applying a principle which has been known and used for ages but which has been applied to shafting bearings only in more recent years. This type of bearing will be dealt with at greater length in a succeeding chapter.

The increased speed at which machine tools are being operated makes the question of providing intermediate supports for long shafts a matter of much greater importance than was formerly the case. If a shaft is deflected while running at a high speed, the action of centrifugal force tends to throw it still further out of alignment, this causes vibration and pounding, and has the tendency to wear the bearings somewhat conical, also there is the danger of the shaft snapping or breaking from this constant hammering.

Deflection of a shaft under these conditions may be determined by the same method as for continuous beams where the load is uniformly distributed. The load will be the weight of the shaft and the support will be the bearings at each end.

The deflection of the shaft due to its own weight is considerable in some cases, and it is important to realise the advantage that is gained by having bearings and hangers so placed along the line to support the shaft to do away with this deflection as much as possible and consequently lessen friction due to deflection.

CHAPTER III

BEARINGS AND HANGERS

There are many kinds of bearings on the market for use in line shafting but any one which will give the minimum of friction is suitable for the purpose.

Roller bearings are proving very popular on some of the newer installations. The object is to provide a hard surface for the rollers to revolve on, a high carbon steel bushing or shaft sleeve, such sleeve to be split spirally which allows such bearings to be applied to existing shafts without dismantling. Advocates claim that when such bearings are properly applied they will reduce the friction as much as 50 %.

A good lubricant is essential to the efficient operation of these bearings. A solidified kind can be used but the liquid is preferable. A poor liquid lubricant is just as good as the best solidified kind. A good liquid lubricant is very much better. This lubricant should contain no acid but should be neutral. The trouble with the solidified lubricant is that the oil will work out of it leaving the residue, a sort of soap, which will gum up the bearings and cause much trouble. With an oil this can never happen.

A roller bearing in common use at the present time is the Hyatt. The distinctive feature of the Hyatt flexible roller bearing is the roller, which is made from a strip of steel wound into a helix or spring of uniform diameter. The greatest advantage of a roller of this construction lies in its flexibility, enabling it to present at all times a bearing along its entire length, resulting in a uniform distribution of load on the roller itself as well as the surfaces on which and in which it operates.

Another type of bearing is one which is provided with a bushing or sleeve and is oiled by various means, most of which are self-oiling and require little attention for their efficient operation. Most of these bearings have an oil reservoir, which oil is fed to the bearing surface by some means or other.

The wick-oiling bearing is a self-oiling bearing providing lubrication to the shaft according to the demands of the service. It is fed from the oil reservoir below to the shaft by capillary attraction.

The ring oiling bearing is one which has a ring which revolves and passes through the oil reservoir. This ring is driven by the friction of its own weight and a continuous supply of oil is maintained from the reservoir to the top of the shaft from whence it flows over the entire bearing surface. Another bearing similar to this is one which has a chain instead of the ring which forms an endless oil conveyor.

CHAPTER IV

BELTS AND PULLEYS

The combination of different types of belts and pulleys in any installation of any size is very important to its efficiency.

The split pulley has many advantages over the solid pulley and its use is nearly always recommended. A mistake is made by many factory managers in using solid, cast-iron pulleys for all line, jack or countershafting for driving machinery. Split pulleys can be placed in position without interference with any other part of the shafting equipment, such as removing couplings, hangers, and pulleys in order to get the new pulley into place. This is valuable when a machine is to be moved to a new location and is of great service when adding new machinery to the line. There are no keyseats or set-screws to mar and spring the shafting. These pulleys can be made to fit almost any size of shafting throughout the plant, all that is necessary is to change the bushings for the different sizes of diameters of the shafts.

Split pulleys are of advantage even on countershafting where tight and loose pulleys are used for starting and stopping, as, after a loose pulley has been run for a number of years, it becomes worn in the bore of the hub, and the pulley will not run smoothly, causing unnecessary noise. The pulley must then be taken off and rebabbitted or rebored and much time can be saved if the pulley is of the split type.

Split pulleys may be of either iron or wood and the loose pulley ; provided with a split iron sleeve in the bore of the hub which can be replaced when worn without much labor or expense. It is always good practice to carry an extra sleeve in stock for all loose pulleys, as an accident is likely to occur at any time due to the neglect of the machine operator or the regular oiler to oil the pulley properly.

Large pulleys should always be used whenever possible as there is less tendency to slip on account of the greater belt contact. An example of this is as follows: A 75 r.p.m. engine, transmitting 100 H.P. from a 5 ft. pulley to a 4 ft. pulley had the distance between the centers of the pulleys 25 ft. Because of the slow engine speed and the relatively small driving

pulley the belt caused considerable trouble by slipping. Its velocity was less than 1200 ft. per minute. A velocity of 4500 ft. per minute would not be too high. A 10-ft. driving pulley and an 8-ft. driven would give the same line shaft speed, and there would be less tendency of the belt to slip due to the greater belt contact. In this case a 40-in. belt was used. By doubling the diameters of the pulleys the belt speed is doubled and its transmission capacity is increased two-fold. A belt only one-half as wide or 20 inches would therefore suffice and its cost would be only one-half as great. The cost of the pulleys would be increased but their increased cost would be counterbalanced by the decreased cost of the belts, in this case the new installation would be $270.00 less.

There are certain general rules which apply in belt calculations which are as follows:

(1) A single ply belt, one inch wide, running at 800 feet per minute, will transmit 1 H. P.

(2) A double ply belt, one inch wide, running at 500 feet per minute, will transmit 1 H. P.

There is a limit to which increasing the size of the pulley will decrease the cost of the installation. This limit would vary with each individual problem and

up to this limit the combined cost of the belt and pulley decreases as the size of the pulley increased. The limiting diameter of standard pulley manufacturers is 10 ft., and it probably would not pay to go beyond this size as special pulleys would probably cost too much to be considered.

Pulleys are commonly made with a crowned face because the convexity keeps the belt on when various other things tend to make it run off. There are various methods and rules for crowning - (1) % of belt width from 1/12 - 1/96; (2) Taper of so much a foot 1/10" - 1/2"; (3) Fancy curves. Crowning the pulley tends to keep the belt in the center of the pulley. The force with which a belt runs to the large end of a cone depends on the width, so that in the case of a belt running on the crown face pulley, if it gets out of center a greater force on one side than on the other tends immediately to force it back to its proper position. A slipping belt will run off a crowned faced pulley quicker than from a straight-faced one. When the danger of slip is great, particularly in the case of a small pulley driven by a large one, it is advisable to use a moderate crown and provide flanges.

There are many types of pulleys in use, a few of which deserve mention. It must be remembered

that pulleys all come so that by an arrangement of sleeves they can be made to fit any size shaft from one very small to one almost the size of the bore. Care must be taken in manufacturing these pulleys to have absolute concentricity of the pulley and bushing so that it will run true.

One kind of pulley is the iron center wood rim pulley. This combination of wood and iron gives high tractile efficiency. The pulleys are made with cast-iron hub and arms, the rim being of wood. The spider is cast with broad pads on the end of each arm. After boring the hub, the pads are turned to a true circle and are concentric with the shaft. A wood rim is then made of hard wood segments built up, and the inside turned to the exact diameter of the spider. Bolts fasten the rim to pads. Then the edges and outer rim face are turned to the proper size, finished and balanced with care. Internal shrinkage strains are entirely eliminated, making a pulley perfectly safe at any practical speed. This combination construction peculiarly adapts it for use in driving machinery subjected to severe shocks, or where the power is applied intermittently, the effect being absorbed within the structure without injury. A pulley of this kind has been tested to a rim speed of 5 1/2

miles per minute with no resultant damage. In this type of pulley lighter belts and less tension can be used with a corresponding reduction in pressure on bearings, all of which results in decreased friction.

A wood split pulley is another form. This pulley is made entirely of wood. The arm construction of a pulley requires more than incidental attention, in fact, it is the weak point in pulley building, and as a chain is no stronger than its weakest link, so likewise is a pulley no stronger than its arm construction. The arms should be made up in pairs extending diametrically across the shaft, from rim to rim, by means of which integral double levers are formed. These arms are dovetailed and wedged into proper recesses made in the rims, then glued and anchored by means of anchor bolts, extending through each end of the arms and into a malleable anchor nut, which is imbedded into the rim.

Another type of pulley is the Split Iron Pulley. The rim is cast whole, then split by fracture on the parting line. When the pulley is mounted on the shaft and the fractured edges of the rim are matched and bolted, they fit together almost as tight as a solid rim pulley. These pulleys are made of cast

iron, are non-flexible and stay exactly round and true and in balance, just as they leave the shops. They don't pull out of shape when put under a belt, and they have no riveted joints to work loose or shear.

CHAPTER V

CLUTCHES

Probably the most important part of efficient operation of line shafting is a clutch which will be strong and powerful, yet efficient.

There is a lack of information given by many manufacturers. They seldom have any information in regard to the "pick-up" capacity of the clutch and they seldom give their starting torque in their catalogs. The purchaser of clutches for mill or shop work, if he buys one large enough to transmit the power wanted at running speed, should make sure it has capacity enough to start up from rest under all conditions of operation. When running fast, the "pick-up" capacity of a clutch is inversely proportional to the speed while its transmitting power is directly proportional to the speed.

The starting torque of the common friction clutch is a constant up to a certain speed of the friction surfaces of the driving shaft, and beyond this point, it rapidly drops. The work done by a clutch in "picking-up" a load is directly proportional to the moment required to turn the mechanism to which it is attached, or, in other words, is directly proportional to the weight of the load.

The power transmitted by a clutch when "picking-up" a load is directly proportional to the square of the velocity of the mechanism to which it is attached. That is to say; if we double the speed of the driving shaft and then throw in our clutch on the same load, the power transmitted to start up the same machine from rest to double the normal speed will be four times as great as the work required of the clutch to start the same machine at normal load in the same time.

There are two clutches which we have given special attention to as being especially adapted to the work required in this special case. They are the Johnson Friction Clutch and the Brown ring oiled clutch.

The Johnson Friction Clutch is manufactured by the Carlyle Johnson Machine Company, of Manchester, Conn. This clutch has but few parts and is very compact. A body fastened to a shaft carries a split ring in which are inserted a pair of levers. A curve shaped wedge, which is made part of a shipper sleeve, forces the levers apart, expanding the ring, bringing its outer surface into frictional contact with the inner surface of the friction cup, the hub of which is made to suit requirements. The leverage is so compounded that it requires but little pressure to operate the clutch.

One screw which moves two taper blocks, set into the levers, adjusts the contact of the ring and cup to any tension. This is easily reached with a screw-driver through a hole in the friction cup. The perfectly smooth shipper sleeve entirely covers the working parts so no dirt can get near them. The double clutch requires but little more space than the single and has two friction cups with hubs, on which can be mounted pulleys, cones, gears, etc., of any diameter and face.

These clutches are small and compact and are very powerful for their size but this type of clutch does not transmit a great deal of power and the largest this clutch is made is up to 6 H. P. at any speed. These clutches have a driving collar which obviates the necessity of keyseating the shafting and a self-oiling bearing which is supplied for greater speeds than 300 R.P.M. and above 500 R.P.M., a bronze self-oiling bearing is supplied.

The Johnson Company makes the following claims for its clutch: (1) It is small, powerful, simple, neat, operating easily and quietly. (2) Has but few parts, each made absolutely interchangeable. (3) It is nicely balanced and runs at high speed without vibration. (4) It is round and smooth, with no protruding parts, making

accidents impossible. (5) No bolts, nuts, links, etc., to become loose and cause trouble. (6) Can be instantly adjusted to any tension with one screw. (7) Working parts are entirely covered and kept free from dirt. (8) It is made both single and double.

The clutch is designed particularly for light power and is not a heavy powered type, and it is seldom that any size is put out to transmit more than from 6 to 7 H. P. at any speed. There are certain conditions where these clutches will transmit up to 30, 40 and 50 H. P. in the larger sizes, if properly made to meet the requirements so that these can be run in oil, and have the proper bronze bearings, etc., but we will not meet this condition in our design.

The Brown Engineering Company of Reading, Pa., put out a clutch especially adapted for this kind of work called "The Ring Oiling Clutch." This clutch is adapted for heavy power and also high speed. It is oiled by placing a receptacle for oil at the end of the sleeve, placing a ring on the shaft, traveling with the shaft and carrying the oil to the top of the shaft, grooving the sleeve spirally, permitting the oil to travel along the grooves and giving the shaft a free and constant flow of oil. The clutch is designed to meet the rulings by the various commissions

on safety devices by enclosing all moving parts in a cast iron housing. By using steel rolls for compression members, and placing hardened steel plates on the discs a great deal of wear is eliminated as a rolling motion is substituted for a sliding motion.

In direct drive work this clutch is especially adaptable. It is mounted on the shaft above each machine with a removable pulley thereon. The sleeves of these clutches are ring-oiling as described above and are as reliable as the regular line shaft hanger bearing. They oil in proportion to the speed and require lubrication but once in four to six weeks, run satisfactorily at line-shaft speeds as high as 800 R.P.M., and are not affected by centrifugal force.

This system is in line with the modern tendency to divide manufacturing plants into departments, assembling machines of a like nature under short lengths of driving, and group driving. With the shafting mounted with the better class of anti-friction bearings, this method of power distribution is one of the most economical in existence. The first cost is less than either the countershaft or individual motor system, and the cost of operation is much less than either.

Another clutch worthy of consideration is the Dodge Solid Friction Clutch, manufactured by the Dodge Manufacturing Company of Mishawaka, Ind. These clutches are of the disc type and made in both split and solid patterns. The compression is in line with the shaft and is not affected by centrifugal force, as is the clamping of the rim or ring type. The split clutch has one disc, filled with hard maple blocks, the end grain of which is presented to the driving and clamping plates. The driving plate is keyed to the shaft; the outside clamping plate, by a movement of a lever, brings the wooden blocks in contact with the driving plate and when in full clutch, the wood-filled disc is securely clamped between the two plates. This clutch is split throughout and can be mounted on the shaft without taking down the shafting or interfering with any other equipment thereon, it has a detachable sleeve, by means of which any type of pulley, sheave, gear or sprocket wheel, may be used. (These articles of any size within the capacity of the clutch.) Another principal feature is the interchangeability of sleeve, hub or quill, by means of which the mechanism may be used for a clutch pulley, a cut-off coupling or a quill outfit. The sleeves may be bored from cast iron, or babbitted or bronze bushing, as desired.

CHAPTER VI

METHOD USED

A general survey was first made of the conditions controlling the various factors in direct line shaft driving. Articles pertaining to the work were read and notes taken in order to get the newest ideas on the subject. Letters were written to manufacturers of line shafting appliances and clutches, and their ideas and catalogs were obtained.

Each machine in the University shop which was to go into the new design was measured and its step cones located. Small cards laid out to a certain scale were cut out to represent these machines and the cones located thereon. The shop was then laid out to size and the various posts and obstructions located. It was decided to put the tool room in the center of the length of the shop and extending out from one side to within three feet of the center. This will give ample room for all tools and supplies necessary. The tools are to be distributed from one central window as better adapted to the peculiar requirements.

The cards representing the machines were then shifted around to get the best arrangements. It was decided to lay the machines out in two groups on

either side of the tool room so that each group would be complete in itself with lathes, planers, and milling machines. In this manner two classes under separate instructors could work absolutely independent of each other. An 8-ft. aisle was allowed down the center of the shop and the machine tools located on either side thereof.

A friction clutch was designed after the manner described in the foregoing chapters. A system of two clutches and a set of planetary gears were used as is shown in the accompanying drawings. By a system of levers, on engaging the right hand clutch, the left hand one is automatically disengaged and the cone is driven the same speed as the shaft. On engaging the left hand clutch the right one is disengaged and the cone direction is reversed. It is now driven through a system of planetary gears which speed up the cone 30 % over the shaft speed.

BIBLIOGRAPHY

Heavy Duty Shafts with two and three Bearings.

Machinery. April, 1914.

Characteristics of Friction Clutches.

Machinery. April, 1914.

Group and Individual Drives.

American Machinist. December 19, 1912.

Split vs. Solid Pulleys.

Power. November 5, 1912.

Crown Face Pulleys.

Machinery. April, 1913.

Factory Shafting Losses.

Practical Engineer. January 16, 1913.

Intermediate Supports for Long Shafts.

Machinery. January, 1913.

Economical Selection of Belts and Pulleys.

Power. April 28, 1914.

Mechanical Engineers Handy Book.

A Driving System for Machine Tools.
Sibley Journal of Engineering. May, 1914.

Multiple Disc Clutch.
Practical Engineer. November 17, 1911.

Comparison of Flat and Step Cones.
Practical Engineer. May 17, 1912.

Effect of Keyways on the Strength of Shafts.
University of Illinois Bulletin. December 19,1909.

The Aligning of Shafting.
Iron Age. October 12, 1911.

Inertia Effects and Shaft Couplings.
Power. June 27, 1911.

Waste of Power in Unaligned Shafting.
Power. October 10, 1911.

The Problem of Cone Friction Clutch Design.
Machinery. February, 1911.

Present Day Factory Construction.

American Architect. June 14, 1911.

Experimental Analysis of a Friction Clutch Coupling.

Journal A. S. M. E. January, 1910.

Some Points Regarding Disc Clutches.

Horseless Age. June 29, 1910.

Experimental Analysis of a Friction Clutch Coupling.

Journal A. S. M. E. October, 1910.

Line Shaft Efficiency, Mechanical and Economic.

Journal A. S. M. E. December, 1909.

Shafting - Pulleys - Belting.

By H. E. Collins.

Power Transmission.

Halsey.

Catalogs and letters from:

Carlyle Johnson Machine Company,
Manchester, Connecticut.

Brown Engineering Company,
Reading, Pennsylvania.

Dodge Manufacturing Company,
Mishawaka, Indiana.

Standard Pressed Steel Company,
Philadelphia, Pennsylvania.

Hyatt Roller Bearing Company,
Milwaukee, Wisconsin.

Kinkead Manufacturing Company,
Boston, Massachusetts.

Approved by:

A. L. Goddard

Superintendent of Shops

June 10, 1915.

Date

89085091114

b89085091114a